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1991 CASPR Spray Aircraft Efficiency Model - Validation Study

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1991 CASPR Spray Aircraft Efficiency Model - Validation Study

by

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Summary

Predictions of the computer code CASPR (Computer Assisted Spray Productivity Routine) were compared to observed data taken during the 1991 Gypsy Moth Eradication Program run by the Utah Department of Agriculture, Division of Plant Industry. After some tuning, the CASPR model was able to predict the total times of the aerial spray operations to within 20 percent. Improvements with the predictive model will come with additional, carefully monitored field data.

The author wishes to extend his appreciation to those individuals connected with the 1991 Gypsy Moth Eradication Program in Salt Lake City, Utah for their cooperation with this validation study. Without their assistance, this data collection and validation would not have been possible: John Anhold, Steve Munsen, Mark Quilter and Patricia Skyler.

Introduction

Predicting the cost and time required for an aerial spray application is a concern to anyone planning such an operation. The computer code CASPR (Computer Assisted Spray Productivity Routine, Ref. 1 and 2) has been developed by the USDA Forest Service to help plan such missions. The 1991 Gypsy Moth Eradication Program conducted by the Utah Department of Agriculture, Division of Plant Industry and the USDA Forest Service (Ref. 3), provided an opportunity to exercise the CASPR model in a real-world situation. This report describes the methods used to gather and analyze data, and the analysis and findings.

Objective

The objective of this study is described in three parts:

1) Exercise the CASPR computer code under real-world conditions and compare its predictions to observed values.

2) Understand conditions under which the model can and cannot be expected to perform well.

3) Suggest possible enhancements to the model that would improve its predictive ability.

Scope

The data for this validation study was gathered by observing spray operations conducted during the 1991 Gypsy Moth Eradication Program by the Utah Department of Agriculture, Division of Plant Industry (Ref. 3). This program targeted for treatment 29,925 acres that encompass portions of Davis, Salt Lake, Summit, Utah, and Wasach counties, Utah. Its purpose was to eradicate gypsy moths in their present location in these counties and prevent further spread within the state.

Code Operation

"The Baltin-Amsden Formula" (Ref. 4) describes a method for estimating the cost of an aerial spray operation. Banaugh (Ref. 5), under USDA Forest Service contract, modified the Baltin-Amsden formula to account for irregularly shaped and topologically varied spray areas. The CASPR code implements Banaugh's procedure on a personal computer. In order to predict time and cost elements of a spray operation, CASPR requires as input specific data including application rate, tank capacity, flying speeds, hourly costs, turning times, and the number and lengths of spray paths to be flown. Given these data, CASPR quickly predicts total times and costs of the spray operation.

Methods

A few simple observation and recording methods provided the data needed to run the CASPR model and additional data for comparison. When more than one observer noted event times for a particular run, their time pieces were synchronized to a standard reference.

Gathering Pre-mission Data

Two types of aircraft were flown during the spray mission: two Bell 206B III and one Hughes 500D helicopters. Before the spraying operations began, the pilots of these aircraft provided information about operational costs (ferrying, turning, spraying, touching up, and loading), operational speeds (ferrying, turning, spraying, and touching up), the expected volume of spray material per load, the application rate, and the expected swath width. A sample form is shown in Figure 1, and the data are shown in Table 3 in the Appendix, along with an application example, shown in Figures 3 to 8, and Table 4.

Observing Spraying and Turning Operations

All of the flight data needed to run the model was gathered by observing and noting the clock times when the aircraft turns the spray on and off, and what the aircraft is doing when the spray is on or off. By calculating the differences in on/off times and adding them together, the total times for spraying, turning, ferrying, and loading can be determined. Observers were given data sheets on which they were to note observations of the spray aircraft and record the times at which the spray was turned on for a spray pass, the spray was turned on for a touchup pass, the spray was turned off for a normal turn, or the spray was turned off for ferrying or reloading (a copy of this data sheet is in the Appendix in Figure 2). By coordinating these data with the load checkers' data sheets, ferry times and loading times could be obtained.

Observers themselves were placed at strategic ground locations or, when possible, in an observation aircraft. Placing ground observers was difficult and often they could not see all of the spray operations because of extreme distance or because the terrain blocked their view. Even aerial observers occasionally missed a spray event because the chase aircraft was turning or was too distant from the spray aircraft. In the future, using additional aerial observers recording redundant data would help reduce the number of missed events. Depending on the terrain, ground-based observers may not be able to collect sufficiently accurate data.

Observing Ferrying and Loading Operations

The standard procedure for load checkers is to record the times of aircraft landing and liftoff. The load checkers' regular data sheets were used to provide these times. The usual procedure for the load checkers is to record times to the nearest minute. These data sheets were very useful in providing loading times for later comparison, but because the ferrying calculations require times to the nearest second, ferrying times were not compared. Loading times were compared, but since the resolution of one minute is large compared to the typical loading time of a few minutes, large differences were common. Future data collection should insist on more precise load checker times.

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Determining the Spray Region Area and Spray Path Length

The area of the spray region and the lengths of the spray paths are two critical pieces of information to CASPR. Unfortunately, these quantities also proved to be the most difficult pieces of data to obtain accurately.

Because many of the spray blocks in this project were so large, often only portions of a block would be treated on any given day. Sometimes two aircraft would treat different portions of the block simultaneously. (In these instances, the two aircraft are viewed as flying separate missions.) After a day's spraying, a map would be marked with the approximate boundaries of the regions treated, along with notes as to the flight paths taken by the aircraft. Later, this geometry was digitized into a computer. The computer was used to calculate the approximate areas of the spray regions and the approximate lengths of the spray paths.

Two aspects of this method introduce inaccuracies into the calculations. The first is that, while the spray block boundaries can be marked very accurately, the smaller spray regions treated on any particular day cannot be marked as accurately. When digitizing the maps, variations in the boundary locations cause variations in the computed area. Second, the terrain treated was often very complex. Hills and canyons cause the actual treated area sizes to differ from those projected onto a flat map. For this same reason flight paths were rarely straight. The pilots would follow the terrain as it curved around corners and rose and dipped in the hills. When approximating flight paths, an effort was made to conform to the gross features of the terrain, but the actual flight paths were more complex and therefore of different lengths.

Entering Data into the CASPR Model

Two "base case" CASPR data sets were created that contained the basic information about each aircraft. From these basic data sets, new data sets were created for each spray region that contained area and flight path length information. When more than one region in the spray block was treated by the same aircraft, all the smaller regions were added together and treated as one larger area. When more than one aircraft was used to treat one or more regions in the same spray block, each aircraft was considered to be on an individual mission.

CASPR models spray areas in two ways. The first, as a rectangular area, was not used in this comparison because none of the spray areas was truly rectangular. The second way, as an "irregularly" shaped area, was used exclusively because it allows the entry of individual flight path lengths.

Determining Data for Comparison with CASPR

Spraying time for each mission could be calculated by adding together the individual spray times for all of the passes. Turning time and touchup time can similarly be computed. The touchup constant used in CASPR is computed by dividing the total touchup spraying and touchup turning time by the total spraying and turning time. The present default value of 0.1 was used in this study. The target material flow rate is known from the pre-mission data, and the loading time can be determined from the load checker data sheets. Thus, the quantities that can be compared are spraying time, turning time, touchup time, total flying time, loading time, total operation time, number of spray cycles, and flow rate.

The [illegible] the grey region and [illegible] length of the spray [illegible] items of information to CASPR. Unfortunately, these quantities were proven to be the most difficult pieces of data to obtain accurately.

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[illegible] Model

Two "base case" CASPR data sets were created that contain [illegible] the basic information [illegible] each aircraft. From these basic data sets, new data sets were [illegible] treated area and flight-path length information. When [illegible] block was treated by one aircraft, all the [illegible] treated as one large area. When more than one aircraft [illegible] regions in the same spray block, each aircraft was considered [illegible]

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[illegible] time for each mission could be calculated by adding together the [illegible] all of the passes. [illegible] measured touchup time [illegible] the touchup constant used in CASPR is computed by dividing the total [illegible] and touchup [illegible] time by the total spraying and [illegible] time. The value of [illegible] used [illegible]. The [illegible] material [illegible] can be determined from the load [illegible] be computed as spraying time [illegible] time, number of [illegible] cycles.

Data Analysis

Table 1 shows percent differences between CASPR's predictions and the observed data for the 13 spray operations considered. A positive number in this table indicates that CASPR overpredicted the value.

In order to increase CASPR's future accuracy, empirical correction factors were introduced permanently into CASPR's internal equations to adjust the results in the direction of the data. The overall average difference between prediction and data was minimized to below one percent.

While the average difference between the CASPR predictions and the observed data was good, there remained a great deal of variability from case to case. Much of this disagreement can be attributed to the inaccuracies involved with estimating areas and path lengths, as previously discussed. Other sources of error may include variations in aircraft speed, mid-mission reconnaissance passes, and timing variations brought about by the observational difficulties discussed previously. The predictions for one case in particular, "Mueller D", differed so greatly from the data (probably because of invalid assumptions about the flight paths), that it was not considered with the rest of the data. Still, on average CASPR predicted the total operation time to within 22% (after correction).

Spraying Time: The most variation of results occurred for this quantity. The difference between predictions and data ranged from -36% to 47%. CASPR calculates this value using an average speed and the total spray path lengths. Variations in these inputs could account for the wild variations in output. The largest errors occurred for runs using the Bell 206B III.

Turning Time: CASPR generally overpredicted this quantity. The difference ranged from -1% to 67%. The model uses an average turning time and the number of turns made to calculate this value and is very sensitive to variations.

Touchup Time: For only two runs was touchup activity reported. For these two runs CASPR underpredicted the time by -25% and -61%. It is interesting to note that the calculated touchup constants were 0.14 and 0.24 for these runs. These values are higher than CASPR's default value of 0.1, as suggested by Banaugh (Ref. 5).

Total Flying Time: CASPR generally overpredicted this value also. The range of errors was -23% to 47%. This value is heavily dependent on the accuracy of its components: spraying time, turning time, and touchup time.

Loading Time: Loading time is measured in whole minutes and is usually from 1 to 4 minutes in length. Therefore if there is any difference between predicted and observed values, it appears large. CASPR takes its predicted number of spray cycles and multiplies it by an average loading time to get this quantity. Thus, loading time accuracy is dependent on measurements of spray path lengths and predictions of aircraft speed. CASPR accurately predicted this value about 30% of the time. The misses ranged from -62% to 100%.

Total Operation Time: This is the sum of spraying time, turning time, touchup time, and loading time. Total operation time can only be as accurate as its components. The error range here is from -25% to 48%.

Data Analysis

Table 1 shows percent differences between [illegible] predictions and [illegible] for the [illegible] considered. A positive number in the table [illegible] CASPR overpredicted the value.

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[illegible] is measured in whole minutes and [illegible] from [illegible] there is any difference between predicted and observed [illegible] its [illegible] number of spray cycles and [illegible] this quantity. Thus loading time accuracy is dependent [illegible] lengths and predictions of aircraft speed. CASPR [illegible] % of the time. [illegible] ranged from [illegible]

[illegible] of [illegible] only be as accurate as its components. The error

Number of Spray Cycles: Like loading time, the number of spray cycles is a small, integer value. If it differs from its predicted value at all, it differs greatly. Still, CASPR correctly predicted this value almost 75% of the time. For the other times CASPR was off by -56% to 100%. CASPR calculates this number based on the total spray path length, the volume of spray material in a single load, its calculation for application rate, and the estimate of aircraft speed.

Flow Rate: It is evident that the flow rate is being predicted consistently. This consistency is due to the fact that CASPR bases its calculation of this value on the application rate, the aircraft speed, and the swath width. All three of these values were constant for the two aircraft types, and compared to a calculated target value. It is not surprising that agreement is good.

Efficiency, Costs and Other Data: Because the applicators arranged a single contract fee for all the spraying done, individual prices for each of the spray operations were not available. Therefore, costs predicted by CASPR (Table 2) could not be compared to actual costs. Even the helicopter pilots indicated that the hourly fee figures provided were "working numbers." Of note in Table 2 are the values for productivity and efficiency. Productivity, the average number of acres treated per hour, varied greatly according to the estimated area, the number of spray passes, and the average length of a turn. Efficiency averaged 55% with a standard deviation of 8%. This value represents spraying time (time spent with the spray boom turned on) divided by total operation time (spraying, flying, and reloading).

Sources of Error

Differences between values predicted by CASPR and observed in the field came from errors in the observed data and from simplifications used in the model itself.

Data for this study were obtained from three sources. The helicopter pilots provided cost, speed, application rate, and swath width information about their aircraft. Spraying, turning, and ferrying times were recorded by ground-based or aerial observers using synchronized clocks. Finally, spray areas and spray path lengths were estimated using topographical maps.

Errors can be associated with all three of these data collection methods in the following ways. Values for spraying speed, application rate, and swath width are all target values. During the spray operation, some variation can be expected. Observers noting spray on and spray off times must decide visually when these events occur. Often this task is made more difficult by distance, lighting, or an obstructed view. Finally, estimating true spray path lengths and areas using topographical maps is a very approximate process.

The spray areas for each mission were indicated by hand drawing the estimated boundary locations on 1:24,000 scale topographic maps. While the corners of the spray blocks could be very accurately placed on these maps, clearly the smaller spray regions could be only approximated. At the scale of these maps, the width of the marking pen line itself represented approximately 100 feet, similar to one swath width. Small deviations in the markings of the spray regions translate to large errors in area and spray path length estimates. Since these two quantities are so essential to CASPR's predictions, these approximations probably account for most of the differences between the data and the predictions.

[illegible] Like loading time, the number of spray cycles [illegible] ... [illegible] differs from its predicted value at [illegible] ... early. [illegible] CASPR [illegible] predicted this value almost [illegible] of the time. For the other [illegible] times, CASPR [illegible] 100%. CASPR calculates this number based on the total spray path length, the volume of spray material in a single load [illegible] calculation for application rate [illegible]

[illegible] It is evident [illegible] the flow rate, in being predicted consistently [illegible] ... to the [illegible] CASPR bases its calculation [illegible] application rate, [illegible] speed, and the swath width. All three of these values [illegible] constant [illegible] and compared to a calculated target value. [illegible]

[illegible] time. Because the application [illegible] ... [illegible] individual spaces for each of the spray [illegible] The [illegible] predicted by CASPR (Table 2) could [illegible] ... Even the helicopter pilots indicated that the [illegible] ... [illegible] Of note in Table [illegible] are the values for [illegible] and [illegible] ... number of acres treated per hour [illegible] ... number of spray passes, and the average length [illegible] ... with a standard deviation of [illegible]. This value [illegible] ... spray boom turned on) divided by total [illegible] (spraying [illegible])

Sources of Error

Differences between values predicted by CASPR or observed in the [illegible] ... from error in the observed data and from simplifications used in the [illegible]

Data for this study were obtained from three sources. The helicopter [illegible] provided cost, speed, application rate, and swath width information [illegible] ... spraying, turning, and ferrying times were recorded by ground-based [illegible] using synchronized clocks. Finally, spray areas and spray path lengths were estimated [illegible] topographical maps.

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Conclusions

The purpose of the CASPR program is to provide an estimate of costs and times related to a proposed spray operation. In this study, CASPR predicted the values for total operation time to within 22% standard deviation. The average difference between prediction and data was 0.1%.

The spray time and turning time were corrected to fit these data. Using the least squares minimization technique common in data analysis, the standard deviation of the error never fell below 20%. Inaccuracies in the data collected are probably about this magnitude. Efforts should be made in the future to increase the quality of the observed data. Increasing the number of ground observers and/or using aerial observers would help greatly. Further studies should be conducted to investigate CASPR's predictions for fixed-wing aircraft and for flat terrain.

When using CASPR to make time and cost estimates, this study has shown that it is essential to estimate accurately the area and spray path lengths to be flown. Thus, the use of larger scale maps is recommended. Alternately, some investigation should be undertaken involving only the simplifying assumption of rectangular spray blocks and how they are related to irregular spray blocks.

[illegible] purposes of the [illegible] [illegible] used [illegible] proposed spray operation [illegible] [illegible] operation time to within 25% standard deviation. The average [illegible] meteorological data [illegible]

The spray time and ferrying times were converted to [illegible] [illegible] [illegible] quences minimization [illegible] [illegible] in data analysis, but [illegible] [illegible] fall below 20% [illegible] [illegible] data [illegible] [illegible] efforts should be made [illegible] the efforts to [illegible] [illegible] [illegible] reducing the number of ground observers and [illegible] [illegible] [illegible] [illegible] studies should be conducted [illegible] [illegible] [illegible] [illegible] for the [illegible]

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Recommendations

If future validation studies are conducted, some recommendations for those studies include:

1) Use multiple observers for each spray operation, preferably with one observer located in an observation aircraft.

2) Place an additional observer at the loading sites to record landing and liftoff times to the nearest second so that ferrying times may be compared.

3) Devise a system of landmarks to mark spray area boundaries. The landmarks should be easily located on a map to allow greater accuracy in determining the actual boundaries of the spray areas and the actual spray path lengths. A position-recording device installed on the spray aircraft that could be referenced to a map would be ideal.

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Table 1. Percent differences between CASPR predictions and observed data. Positive numbers indicate CASPR over-predicted the value, while negative numbers indicate under-prediction.

Treatment Block Areas	Spraying Time	Turning Time	Touch-up Time	Total Flying Time	Loading Time	Total Operation Time	Num of Spray Cycles	Flow Rate
Mt. Dell A	10	5	-25	4	-25	-1	0	-9
Mt. Dell B	11	11	n/a	11	-45	-2	0	-9
Knudsen	3	6	-61	-8	0	-6	0	-7
Burr Fork	-16	4	n/a	-7	-50	-6	0	-9
Bear Hollow	-14	10	n/a	-4	-33	-10	0	-7
Miller A	41	15	n/a	38	100	48	100	-9
Miller B	-31	48	n/a	-6	0	-5	0	-7
Mueller A	-20	22	n/a	-11	0	-9	0	-9
Mueller B	47	46	n/a	47	100	59	100	-7
Mueller C	-19	19	n/a	-11	-33	-18	0	-9
Red Butte	-15	-1	n/a	-11	-62	-25	-56	-9
Deaf Smith	-36	647	n/a	-23	100	-11	-33	-9
Big Bear	0	0	n/a	0	0	0	0	-9

Table 2. Some additional predicted values from CASPR.

Treatment Block Areas	Aircraft	Total Operation Cost ($)	Cost per Unit Area ($/ac)	Cost per Unit Time ($/hr)	Productivity (ac/hr)	Efficiency (%)
Mt. Dell A	Hughes	348.82	.85	423.41	496.46	57
Mt. Dell B	Hughes	319.43	1.17	419.22	356.97	51
Knudsen	Bell	43.76	.55	250.00	454.74	45
Burr Fork	Hughes	84.89	1.28	407.07	318.41	42
Bear Hollow	Bell	48.72	.73	213.49	290.95	44
Miller A	Bell	124.79	.54	383.29	706.42	62
Miller B	Hughes	30.79	.41	196.75	485.61	40
Mueller A	Hughes	67.72	.49	392.82	806.32	53
Mueller B	Bell	43.27	.38	180.48	479.68	58
Mueller C	Hughes	47.46	.72	365.81	508.71	49
Red Butte	Hughes	404.63	.45	416.65	931.89	57
Deaf Smith	Hughes	122.35	.41	385.68	942.54	58
Big Bear	Hughes	144.57	.72	397.16	552.18	49

Appendix

This appendix contains the following information:

1) Data sheet used to collect pre-mission data for CASPR (Figure 1).

2) Data sheet used to collect spray events times during actual spraying operations (Figure 2).

3) Summary of pre-mission data for Bell 206B III and Hughes 500D aircraft (Table 3).

4) Map of Knudsen Corner, showing spray boundaries, and spray paths (Figure 3).

5) Observed data for the Knudsen Corner spray operation (Table 4).

6) CASPR program input and output screens for the Knudsen Corner spray operation (Figures 4-8).

Pre-Mission Aircraft Data Sheet

What is the hourly cost of operating the aircraft while

- Ferrying: ______________________________
- Turning: ______________________________
- Spraying: ______________________________
- Touching up: ______________________________

What is the hourly cost while fueling and loading the aircraft with spray material:

____

How long does it take to refuel and reload the aircraft with spray material between cycles (the time is from wheels down to wheels up):

____

What is the tank capacity of the spray system: ________________

At what speed will the aircraft fly while

- Ferrying: ______________________________
- Turning: ______________________________
- Spraying: ______________________________
- Touching up: ______________________________

What is the spray application rate: ______________________

What is the swath width: __________________________

Figure 1. Sample pre-mission aircraft data sheet.

CASPR DATA SHEET

NAME: BLOCK: DATE:

PASS	ON TIME	OFF TIME	CONDITION	COMMENTS

ALL TIMES IN HH:MM:SS

→ Ferry
↩ Turn
0 Missed condition
T Touch up

Clock Calibration

Name: Time:
Name: Time:
Name: Time:
Name: Time:

Figure 2. CASPR observation data sheet used for collecting spray on and spray off times and events.

Table 3. Pre-mission aircraft data showing costs, speeds, and target values for application rate and swath width.

	Bell 206B III	Hughes 500D
Ferrying Cost ($/hr)	250	240
Turning Cost ($/hr)	250	475
Spraying Cost ($/hr)	250	475
Touchup Cost ($/hr)	250	475
Loading/Fueling Cost ($/hr)	0	50
Avg. Loading Time (min)	2	2
Load Size (gal)	70	70
Ferrying Speed (mph)	80	100
Turning Speed (mph)	35	20
Spraying Speed (mph)	70	75
Touchup Speed (mph)	70	75
Application Rate (gal/acre)	0.5	0.5
Application Rate (gal/min)	7.5	7.5
Swath Width (feet)	100	90

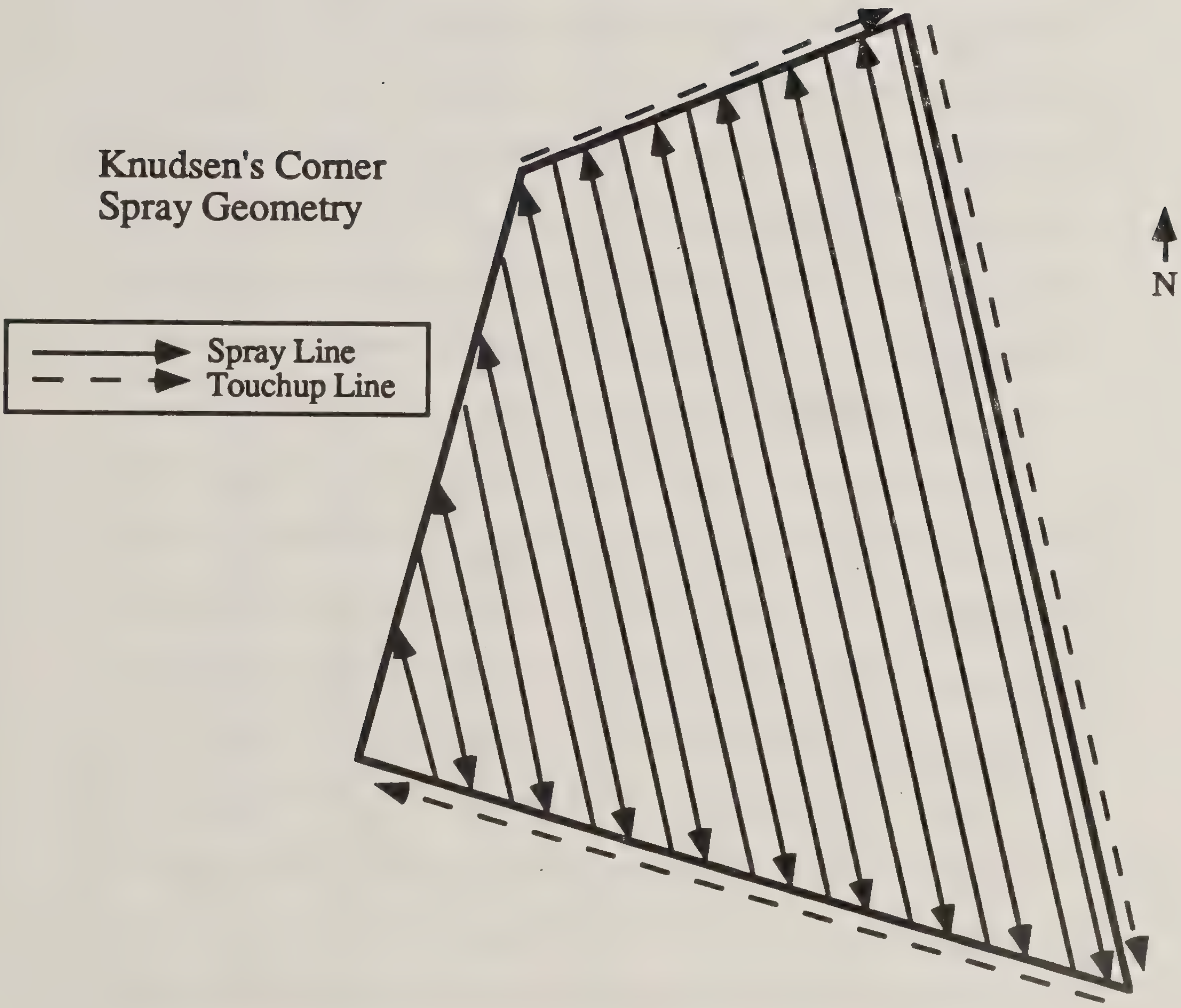

Figure 3. Knudsen Corner spray block geometry showing spray lines and touchup lines (not to scale).

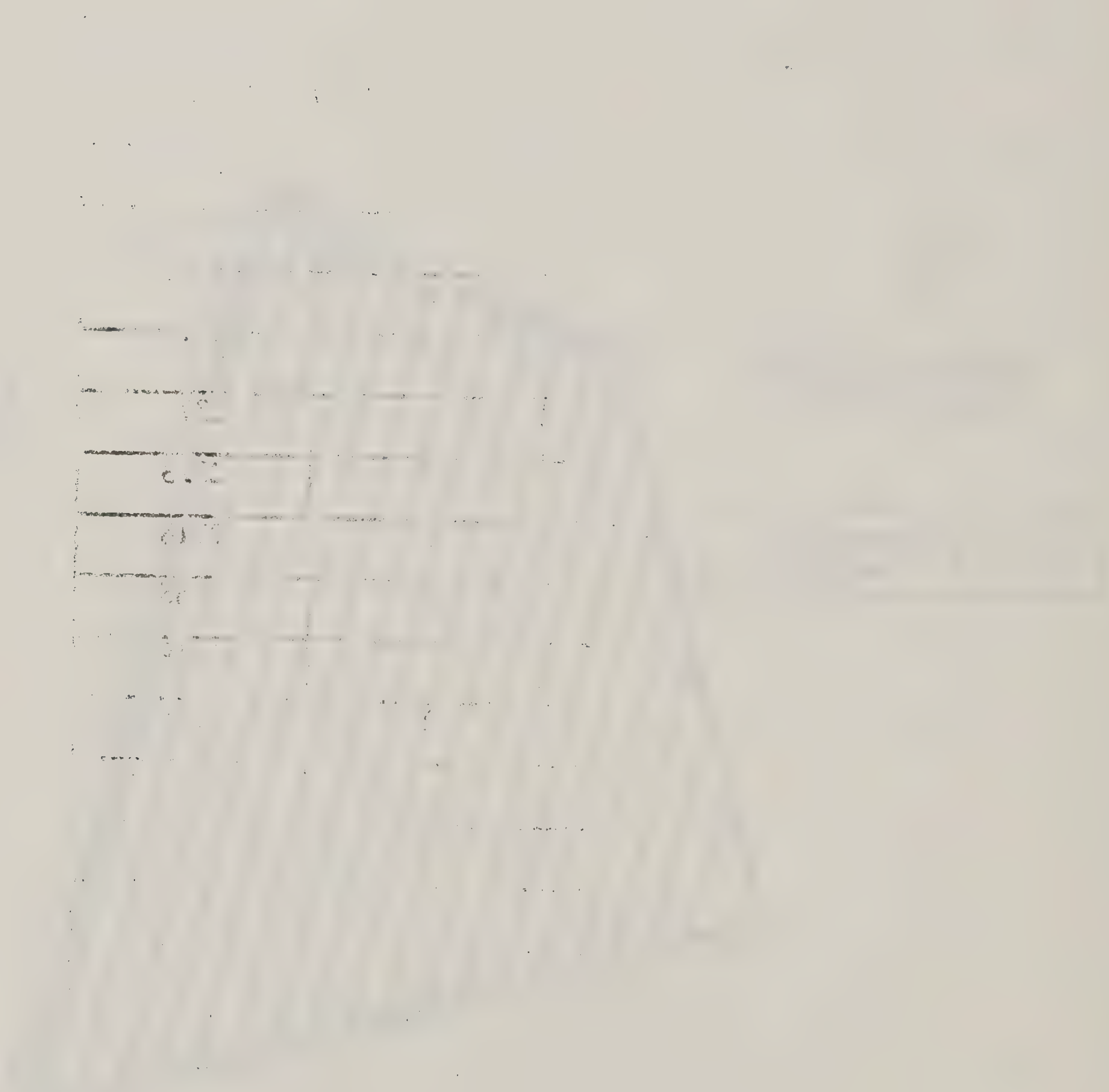

Table 4. Observed data for Knudsen Corner.

Pass	Spraying Time (sec)	Turn Time (sec)	Length (ft)
1	18	17	2746
2	21	18	2693
3	17	15	2587
4	21	16	2534
5	17	17	2429
6	17	20	2376
7	10	13	2323
8	12	16	2218
9	7	11	2165
10	8	14	2059
11	10	23	2006
12	8	14	Touch Up
13	24	20	Touch Up
14	22	20	Touch Up
15	28	17	1637
16	26	15	1162
17	20	-	686

Area = 0.1243 mi^2 = 79.6 acres
Total Spraying Time = 232 min
Total Turning Time = 212 min
Average Turning Time = 17 sec

General Data Worksheet

Application Rate :	.5	gal/acre
Tank Capacity :	70	gallons
Swath Width :	100	feet
Spray Speed :	70	MPH
Ferry Speed :	70	MPH
Turning Time :	16.6	seconds
Aux. Ferry Dis. :	0	miles
Num. Aux. Turns:	0	
Touchup Constant:	.24	
Spraying Cost Rate :	250	$/hour
Ferrying Cost Rate :	250	$/hour
Turning Cost Rate :	250	$/hour
Touchup Cost Rate :	250	$/hour
Loading Cost Rate :	250	$/hour
Loading Time/Cycle :	2	minutes

Press F1 for help, F2 or ESC when finished

Figure 4. CASPR general data worksheet as it appears on the computer screen.

Spray Path Worksheet

Spray Area (ac)= 79.6

Spray Line No.	Spray Line Len. (feet)	Number of Spray Paths Associated With Spray Line	Total Length Of Spray Paths (feet)
1	2746	1	2746
2	2693	1	2693
3	2587	1	2587
4	2534	1	2534
5	2429	1	2429
6	2376	1	2376
7	2323	1	2323
8	2218	1	2218
9	2165	1	2165
10	2059	1	2059
		Tot.= 14	Tot.= 29621
			Tot.= 5.610038 (miles)

Press F1 for help, F2 or ESC when finished, F3 to enter Spray Area

Figure 5. CASPR spray path worksheet as it appears on the computer screen.

```
                    Calculation Summary

Total Operation Cost:            $47.58
Total Operation Time:             11.42 minutes

Cost per unit time:             $250.00 per hour
Cost per unit area:                $.60 per acre

Productivity:                    418.21 acres per hour
Efficiency:                        50.7%

Total Flying Cost:               $39.25
Total Loading Cost:               $8.33

Total Flying Time:                 9.42 minutes
Total Loading Time:                   2 minutes


       Press F1 for help, any other key for next page
```

Figure 6. Calculation summary, screen 1 of CASPR output showing total costs and times.

```
                   Calculation Breakdown

Total Spray Area:                  79.6 acres
Material Flow Rate:                7.07 gallons per minute

Spray Cycle Distance:             11.55 miles
Number of Spray Cycles:               1
Total Spray Distance:              5.61 miles

Number of Spray Turns:               14
Number of ferry Turns:                2
Number of Auxiliary Turns:            0
Total Number of Turns:               16

Spraying Time:                     3.97 minutes
Ferrying Time:                        0 minutes
Turning Time:                      3.63 minutes
Touchup Time:                      1.82 minutes
Total Flying Time:                 9.42 minutes

       Press F1 for help, any other key for next page
```

Figure 7. Calculation breakdown, screen 2 of CASPR output showing time and distance subtotals.

```
                              Time and Cost
               |
Total Time     |__________________________________________________ 100%
Flying Time    |_________________________________________ 82%
Load Time      |_________ 18%
Spray Time     |__________________ 35%
Ferry Time     | 0%
Touchup Time   |________ 16%
Turning Time   |________________ 32%
               |
               |
Total Cost     |__________________________________________________ 100%
Flying Cost    |_________________________________________ 82%
Load Cost      |_________ 18%
Spray Cost     |__________________ 35%
Ferry Cost     | 0%
Touchup Cost   |________ 16%
Turning Cost   |________________ 32%
               |
               +--------------------------------------------------
               0    10   20   30   40   50   60   70   80   90   100
                              Percent of Total

               Press F1 for help, any other key to continue
```

Figure 8. CASPR time and cost graph, showing subtotals relative to total time and cost.